Aircraft Measurements of Tropospheric Aerosol in Antarctica

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with essential support from:
R. Treffeisen, T. Garbrecht, J. Höltig, K. Hara, DLR flight crew, Neumayer and Syowa staff

Why aerosol measurements in the Antarctic troposphere?

Arctic

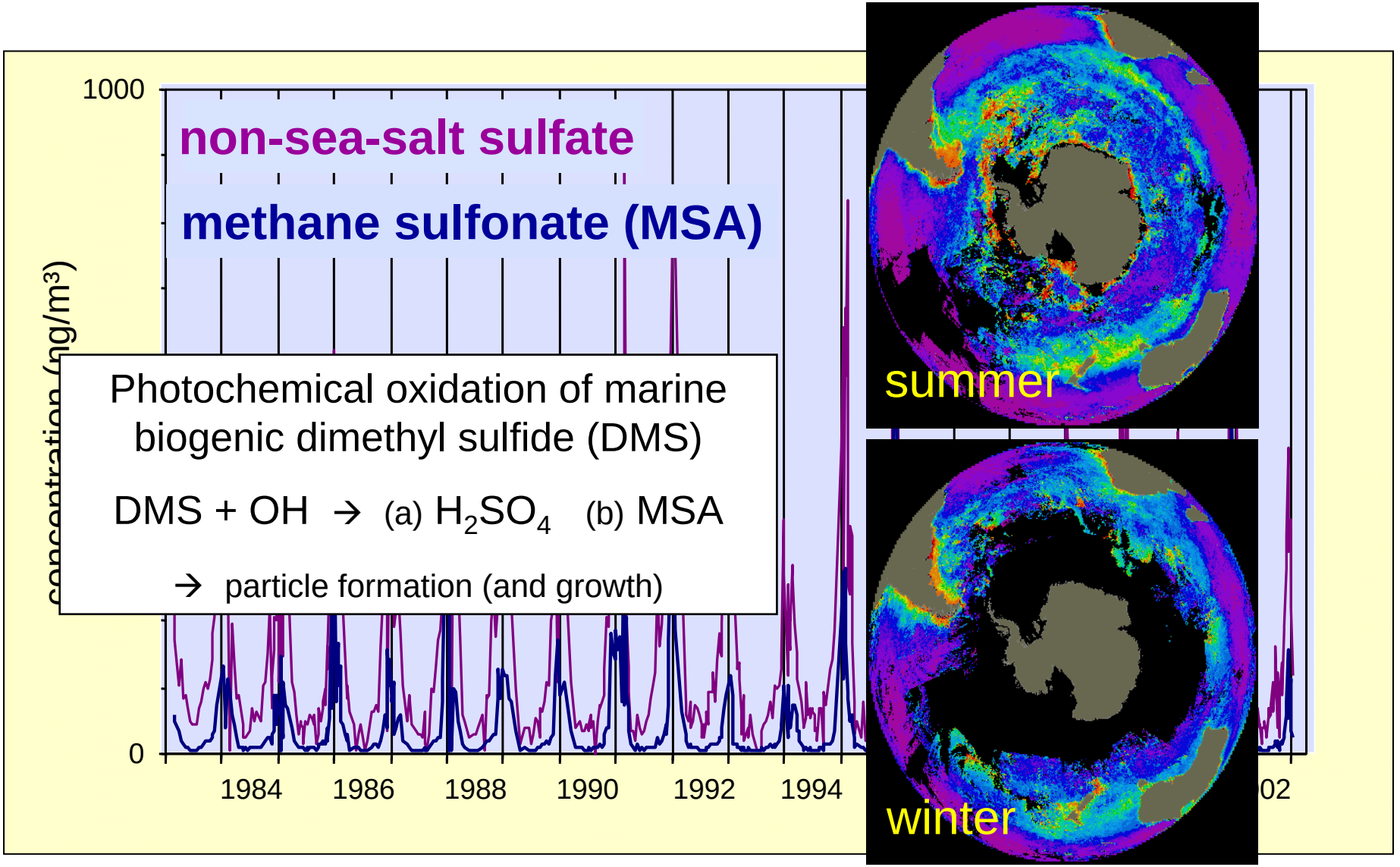
- distinct saisonal cycle in aerosol properties: clean conditions in summer / anthropogenic pollution in winter/spring (Arctic haze)

Antarctica

- it's clean; aerosol radiative effects considered to be unimportant
- but: vertical aerosol distribution virtually unkown
- most information on tropospheric aerosol available from coastal Antarctic sites, but ice cores are drilled mainly on the plateau (> 3 km altitude)
- knowledge of aerosol transport pathways is important, but not well understood at present

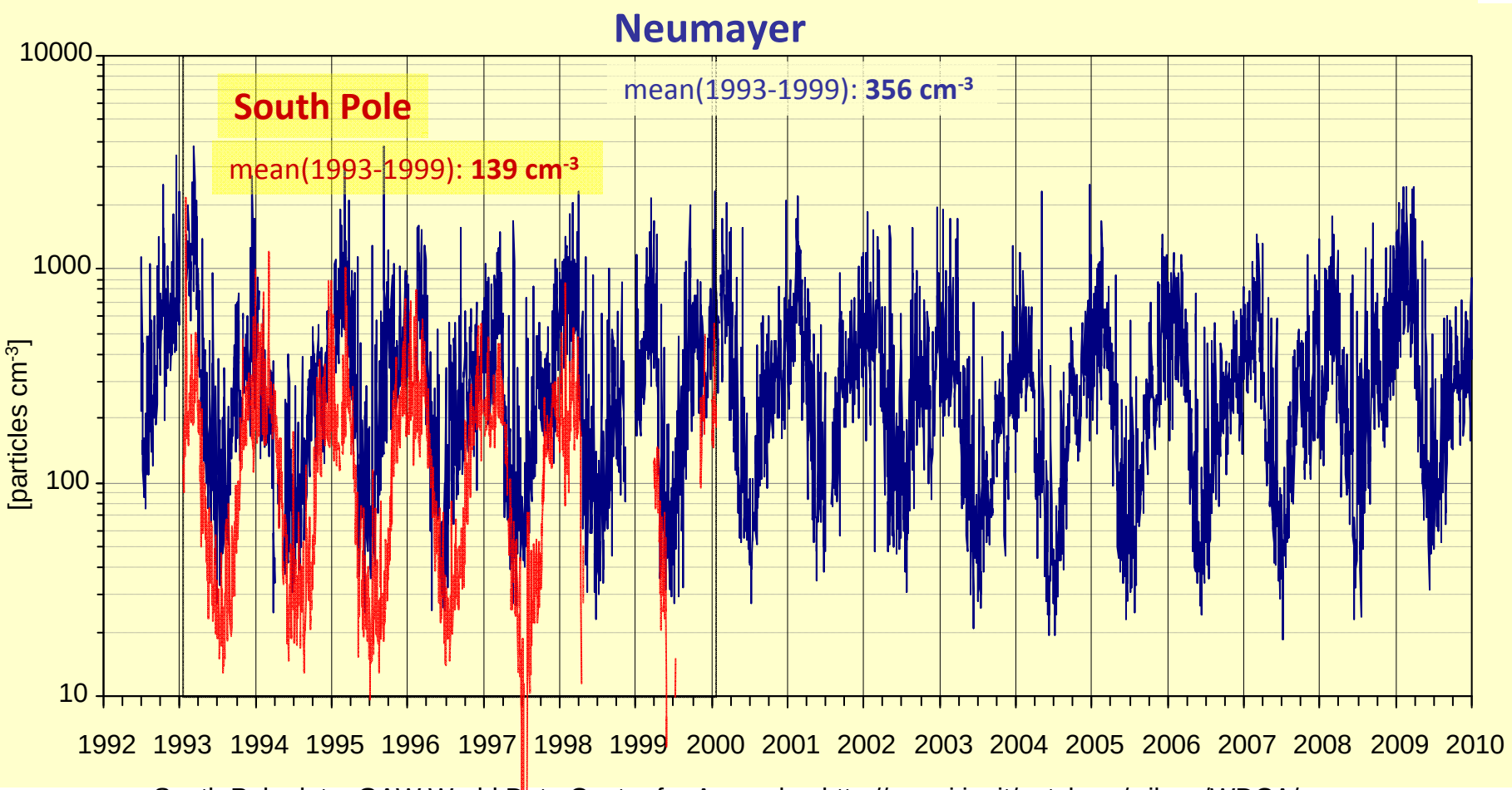
➔ aerosol vertical profiles? can we learn from them?

Aerosol biogenic sulfur record at Neumayer (1983-2002)



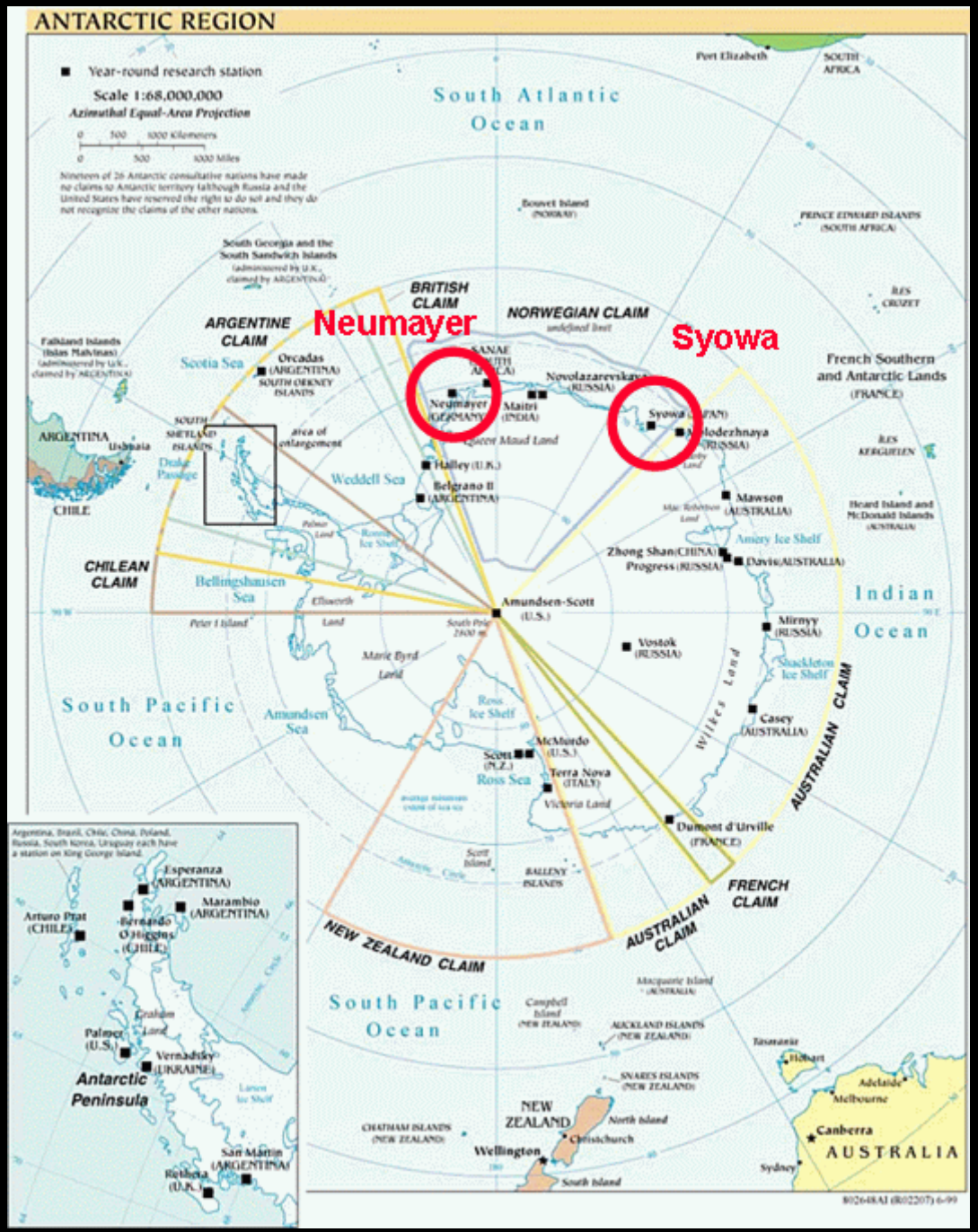
Nimbus-7 Coastal Zone Color Scanner, NASA

Number concentration of (ultra)fine particles:
Seasonal cycle of condensation particles at Neumayer & South Pole

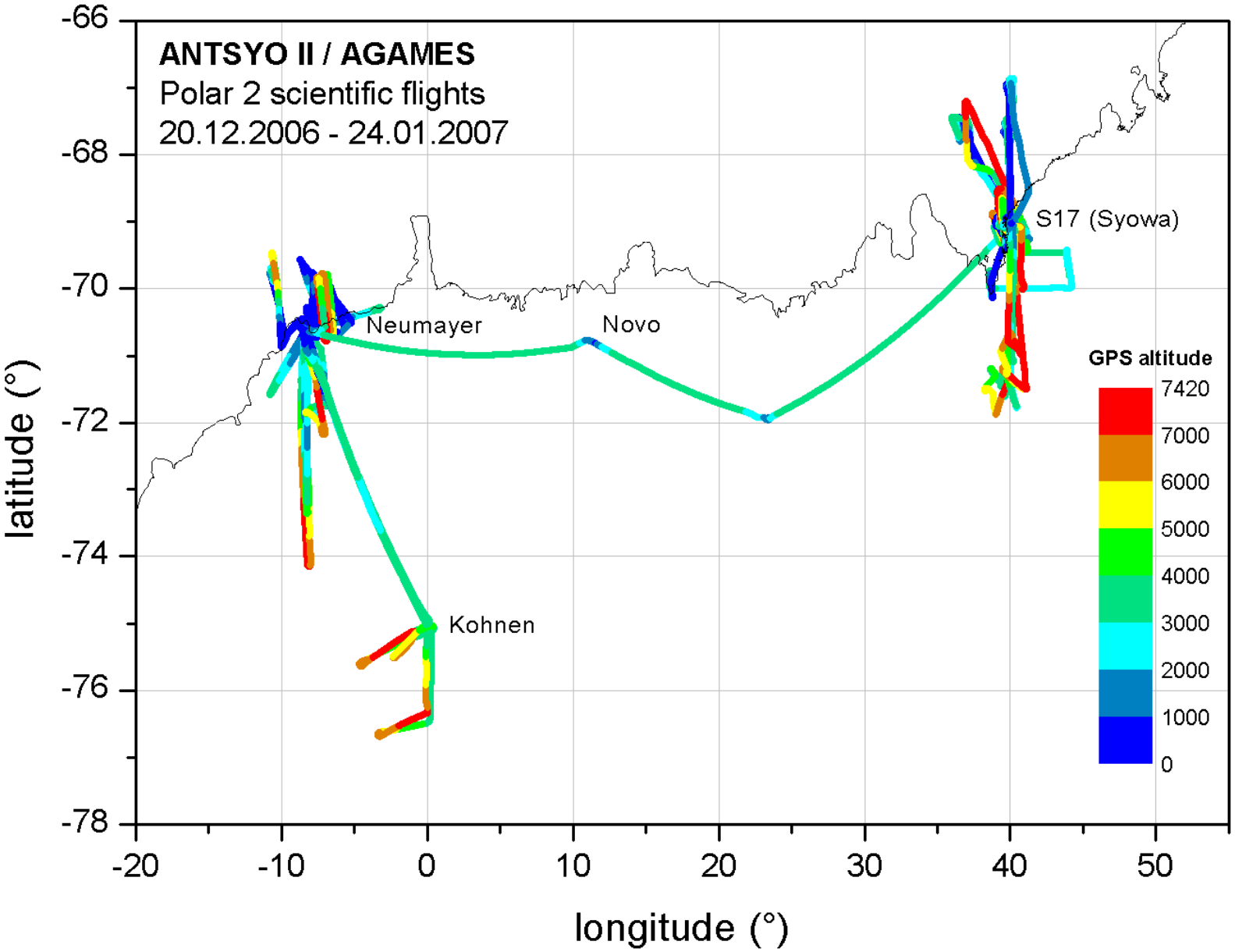


South Pole data: GAW World Data Centre for Aerosols - http://rea.ei.jrc.it/netshare/wilson/WDCA/
Neumayer data: R. Weller, AWI

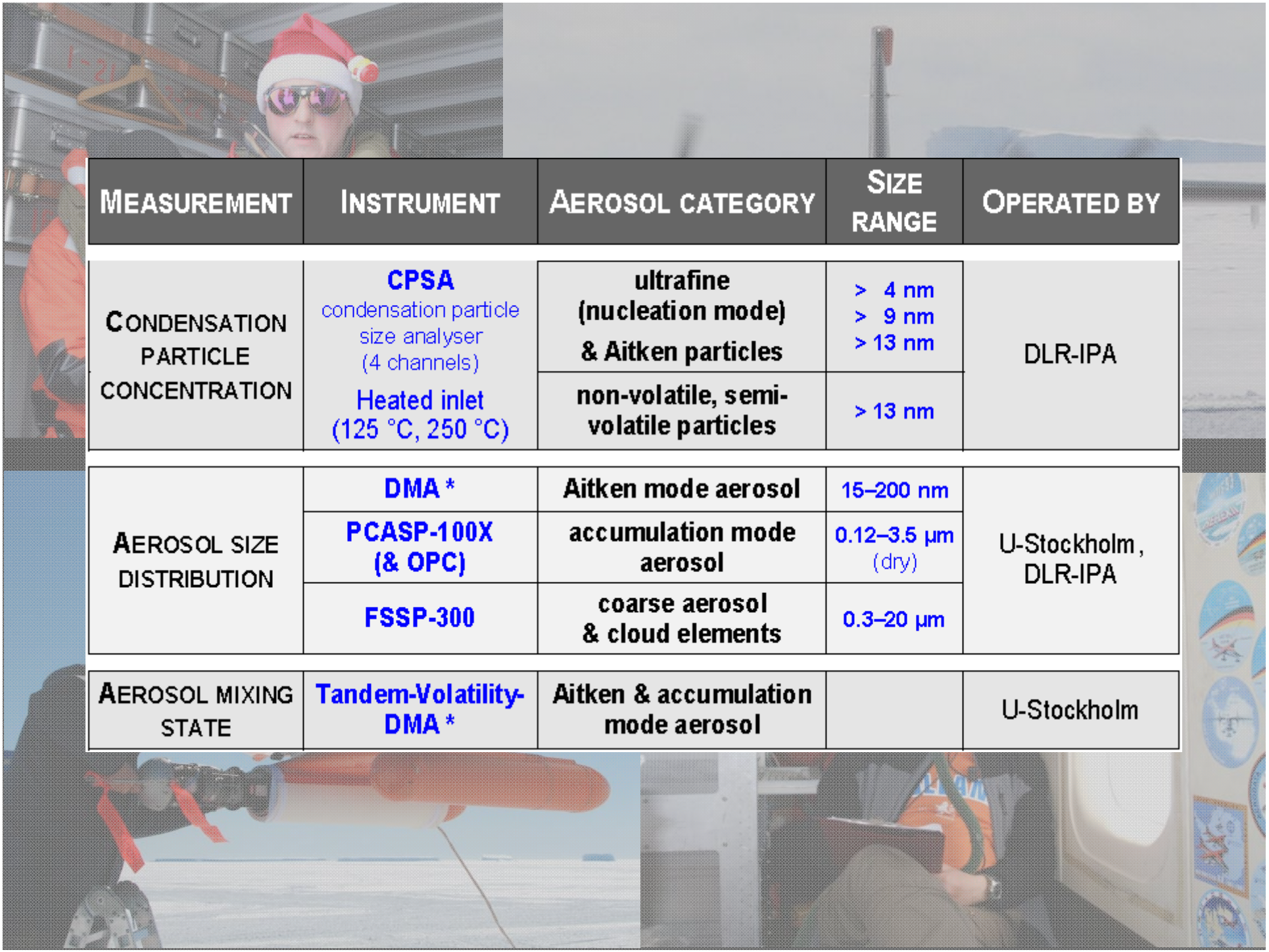
Time period of science flights	20-Dec-2006 until 26-Jan-2007
Total science flight time	88.5 hours
Number of flights	37 flights in total
	15 flights in Neumayer area (20.-31.12.2006) (including 2 flights from Kohnen)
	15 flights in S17 area (7.-24.01.2007)
	6 ferry flights between NM and S17 (with measurements) on 5.01. and 26.01.2007
	17 flights up to 6-7 km altitude
Web page with campaign info	http://www.pa.op.dlr.de/aerosol/agames/ (campaign log, photo gallery, weekly reports)


ANTARCTIC REGION
Year-round research station
Scale 1:68,000,000
Azimuthal Equal-Area Projection
Nineteen of 26 Antarctic consultative nations have made no claims to Antarctic territory (although Russia and the United States have reserved the right to do so) and they do not recognize the claims of the other nations.
South Atlantic Ocean
South Pacific Ocean
Indian Ocean
Neumayer
Syowa
BRITISH CLAIM
NORWEGIAN CLAIM
ARGENTINE CLAIM
CHILEAN CLAIM
AUSTRALIAN CLAIM
FRENCH CLAIM
NEW ZEALAND CLAIM
Port Elizabeth
SOUTH AFRICA
Bouvet Island (NORWAY)
PRINCE EDWARD ISLANDS (SOUTH AFRICA)
ILES CROZET
South Georgia and the South Sandwich Islands
Falkland Islands (Islas Malvinas)
Orcadas (ARGENTINA) SOUTH ORKNEY ISLANDS
Scotia Sea
SANAE (SOUTH AFRICA)
Novolazarevskaya (RUSSIA)
Neumayer (GERMANY)
Maitri (INDIA)
Syowa (JAPAN)
Molodezhnaya (RUSSIA)
Queen Maud Land
French Southern and Antarctic Lands (FRANCE)
ILES KERGUELEN
ARGENTINA
Ushuaia
CHILE
SOUTH SHETLAND ISLANDS
area of enlargement
Drake Passage
Weddell Sea
Halley (U.K.)
Belgrano II (ARGENTINA)
Mawson (AUSTRALIA)
Heard Island and McDonald Islands (AUSTRALIA)
Mac Robertson Land
Amery Ice Shelf
Zhong Shan (CHINA)
Progress (RUSSIA)
Davis (AUSTRALIA)
Palmer Land
Russell Ice Shelf
Bellingshausen Sea
Ellsworth Land
Peter I Island
Amundsen-Scott (U.S.)
South Pole 2800 m
Vostok (RUSSIA)
Mirnyy (RUSSIA)
Marie Byrd Land
Shackleton Ice Shelf
Wilkes Land
Ross Ice Shelf
Amundsen Sea
Casey (AUSTRALIA)
McMurdo (U.S.)
Scott (N.Z.)
Terra Nova (ITALY)
Ross Sea
Victoria Land
Dumont d'Urville (FRANCE)
Scott Island
BALLENY ISLANDS
Antarctic Circle
Macquarie Island (AUSTRALIA)
Campbell Island (NEW ZEALAND)
AUCKLAND ISLANDS (NEW ZEALAND)
Tasmania
Hobart
Adelaide
Melbourne
Canberra
AUSTRALIA
Sydney
SNARES ISLANDS (NEW ZEALAND)
NEW ZEALAND
North Island
Christchurch
CHATHAM ISLANDS (NEW ZEALAND)
Wellington
South Island
Argentina, Brazil, Chile, China, Poland, Russia, South Korea, Uruguay each have a station on King George Island.
Esperanza (ARGENTINA)
Marambio (ARGENTINA)
Arturo Prat (CHILE)
Bernardo O'Higgins (CHILE)
Graham Land
Palmer (U.S.)
Vernadsky (UKRAINE)
Antarctic Peninsula
Larsen Ice Shelf
San Martin (ARGENTINA)
Rothera (U.K.)
80264RAI (R02207) 6-99

Flight tracks of Polar 2 science flights during AGAMES

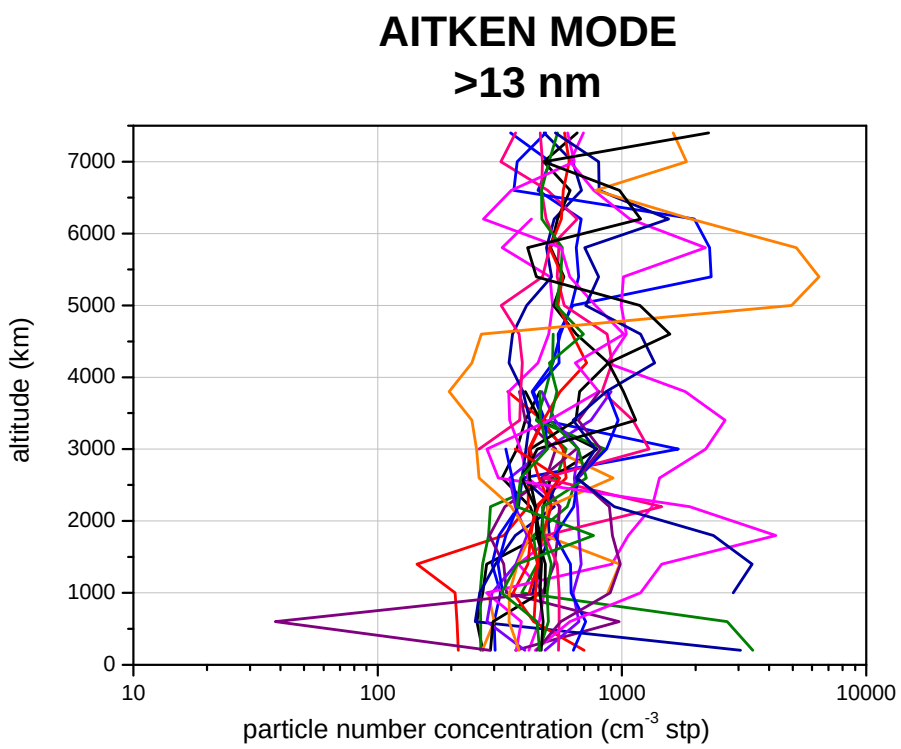


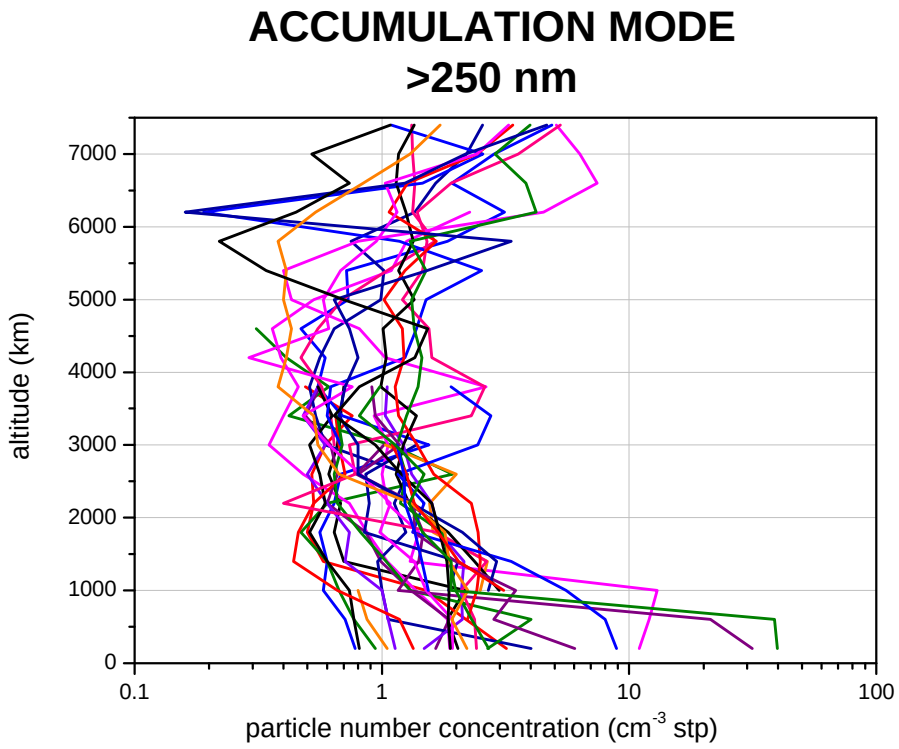
et al.



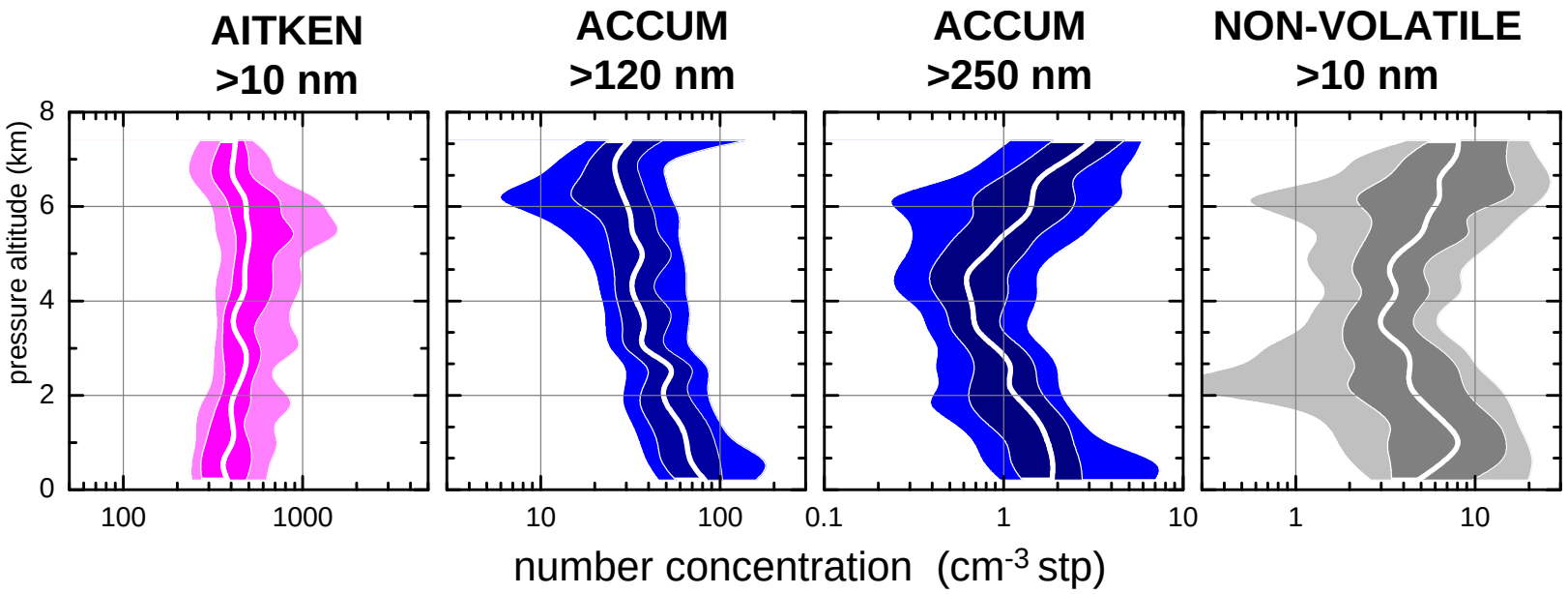
MEASUREMENT	INSTRUMENT	AEROSOL CATEGORY	SIZE RANGE	OPERATED BY
CONDENSATION PARTICLE CONCENTRATION	**CPSA** condensation particle size analyser (4 channels) Heated inlet (125 °C, 250 °C)	ultrafine (nucleation mode) & Aitken particles	> 4 nm > 9 nm > 13 nm	DLR-IPA
		non-volatile, semi-volatile particles	> 13 nm	
AEROSOL SIZE DISTRIBUTION	**DMA ***	Aitken mode aerosol	15–200 nm	U-Stockholm, DLR-IPA
	PCASP-100X (& OPC)	accumulation mode aerosol	0.12–3.5 µm (dry)	
	FSSP-300	coarse aerosol & cloud elements	0.3–20 µm	
AEROSOL MIXING STATE	**Tandem-Volatility-DMA ***	Aitken & accumulation mode aerosol		U-Stockholm

Vertical distribution of aerosol



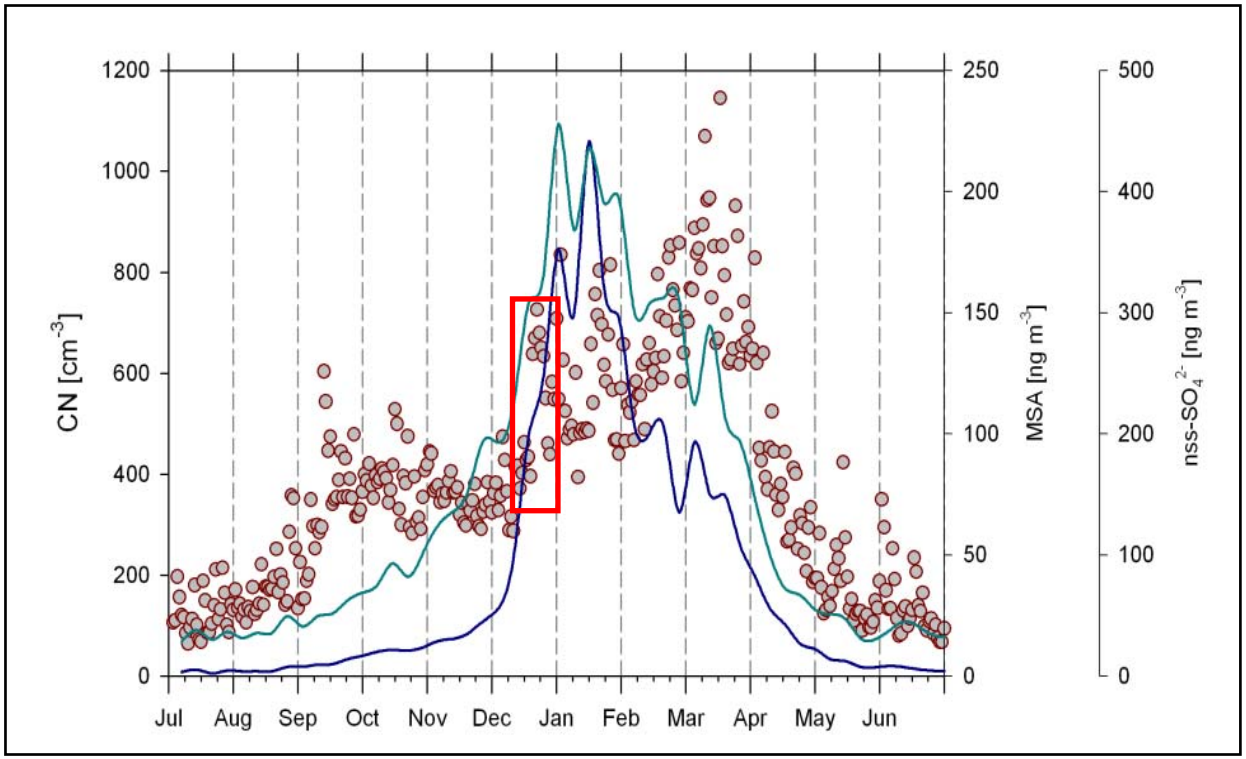


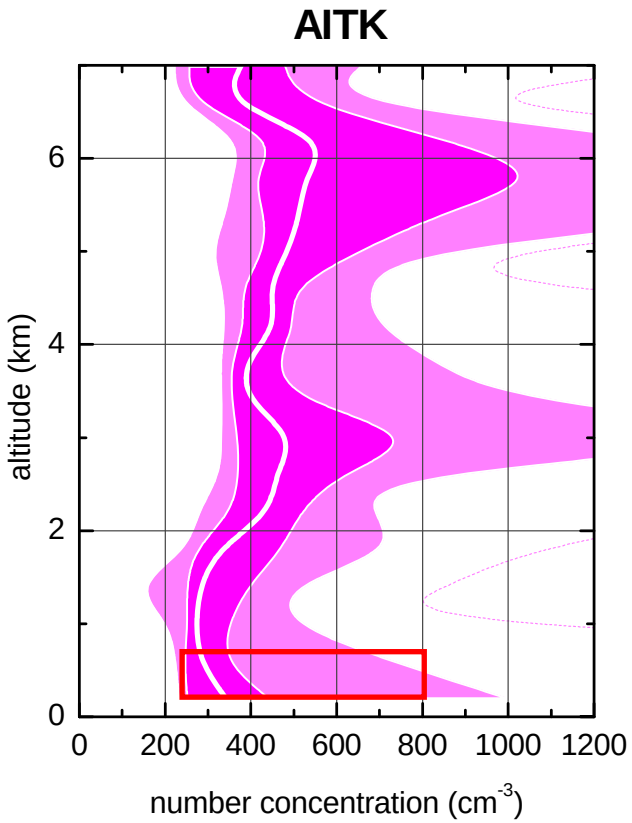
Vertical distribution of aerosol



- Profiles: Median, 10-, 25-, 75-, 90-percentiles per 400 m altitude bin
- Logarithmic concentration scale,
  concentrations corrected to standard conditions (stp)
- In-cloud data excluded from data set

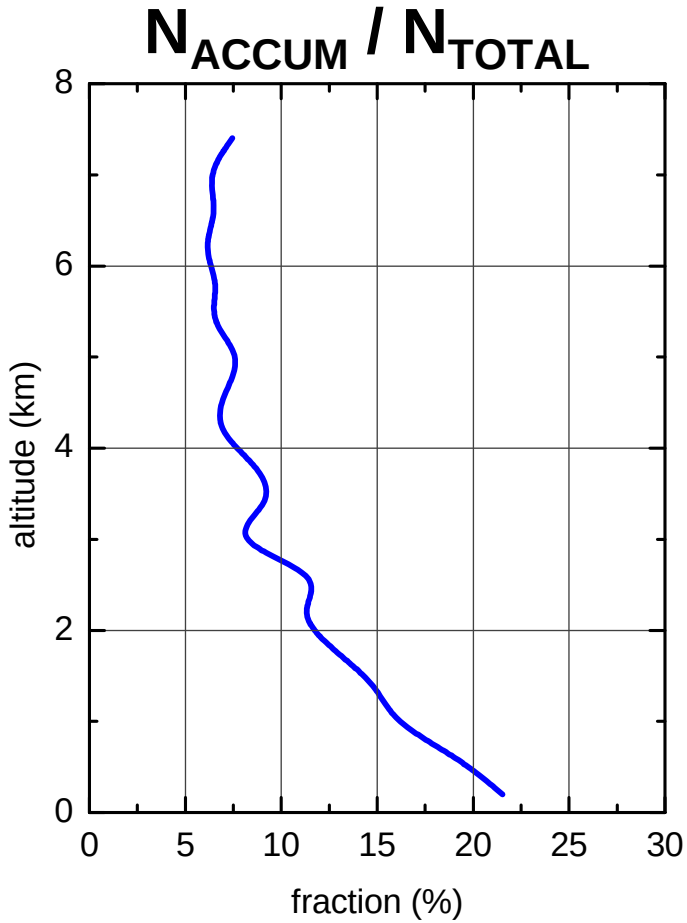
Mean annual cycle of CN at Neumayer compared with the aircraft measurements

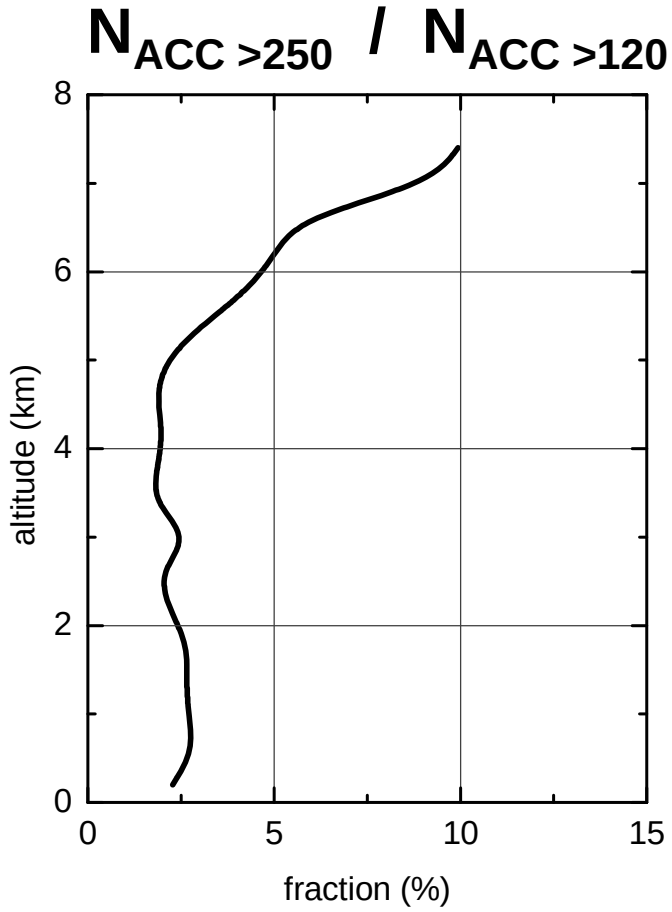




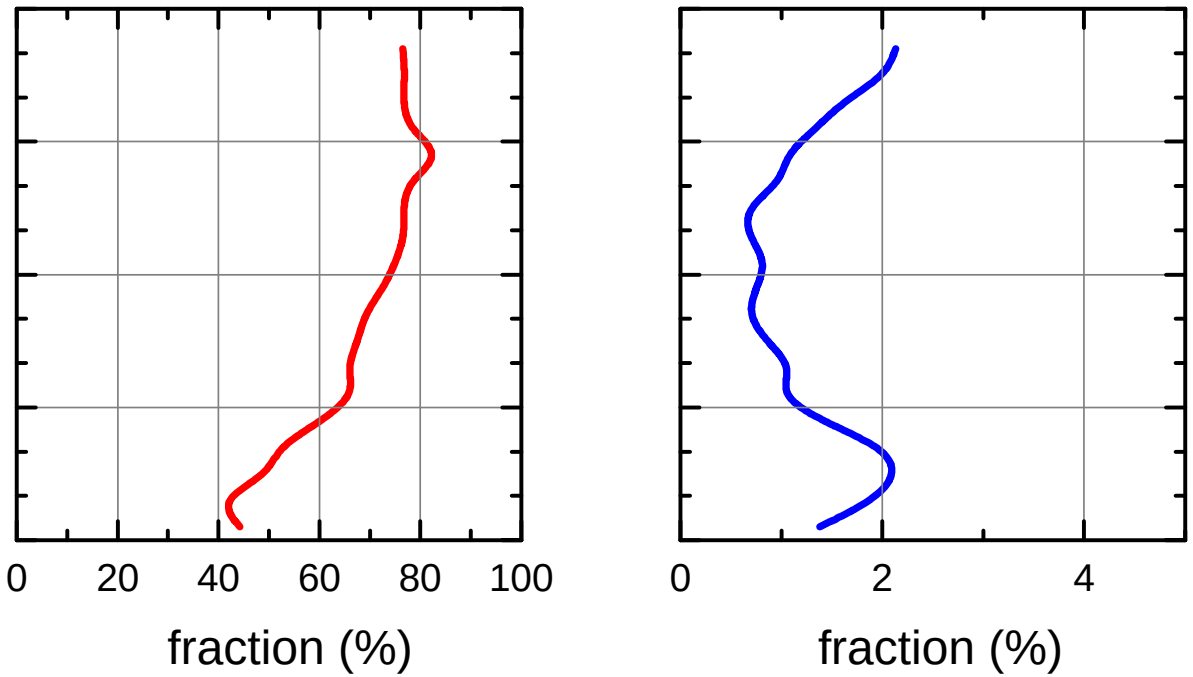
➔ good general agreement in number concentrations

Changes in size distribution with altitude



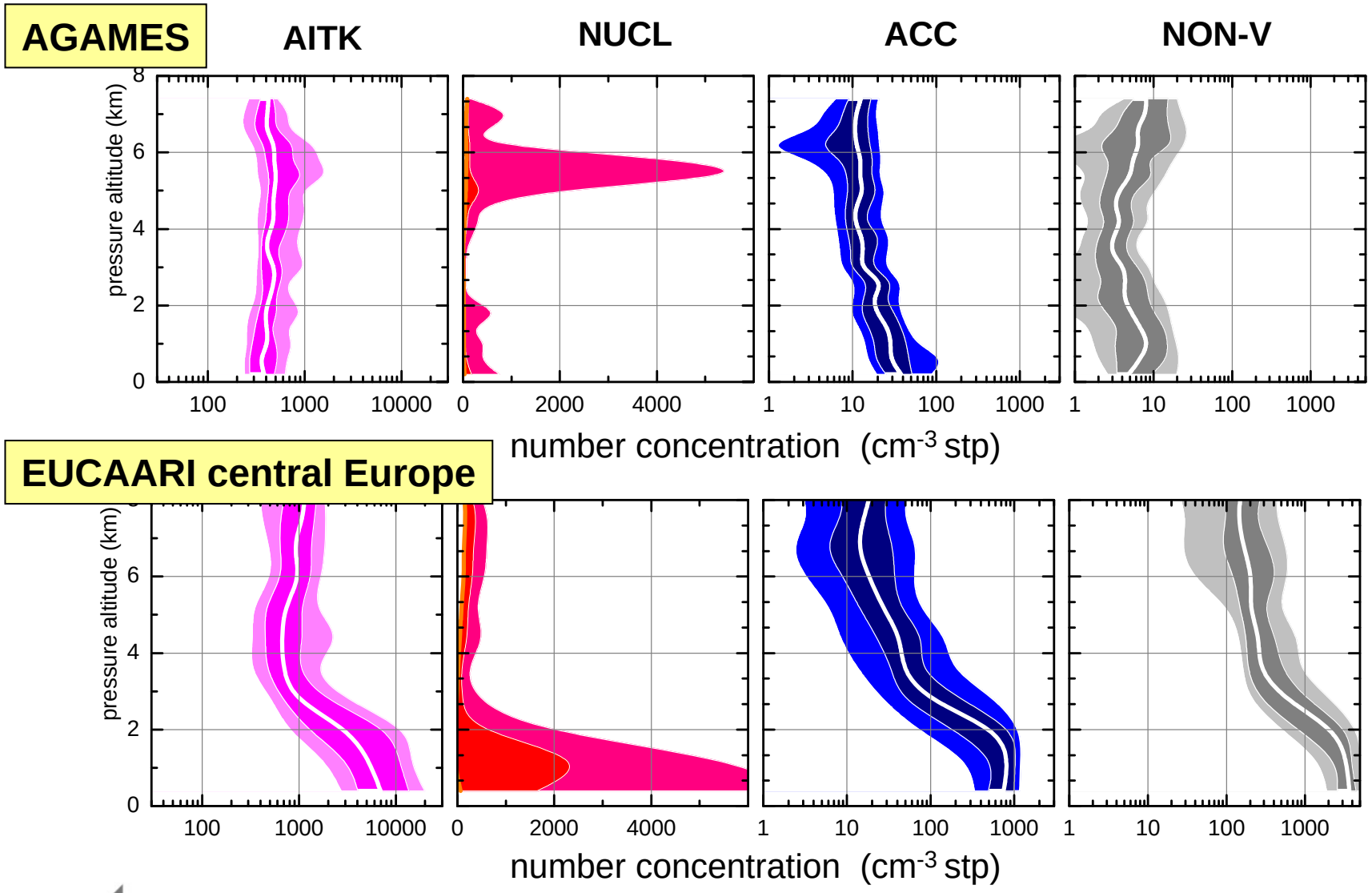


Volatile and non-volatile particle fractions

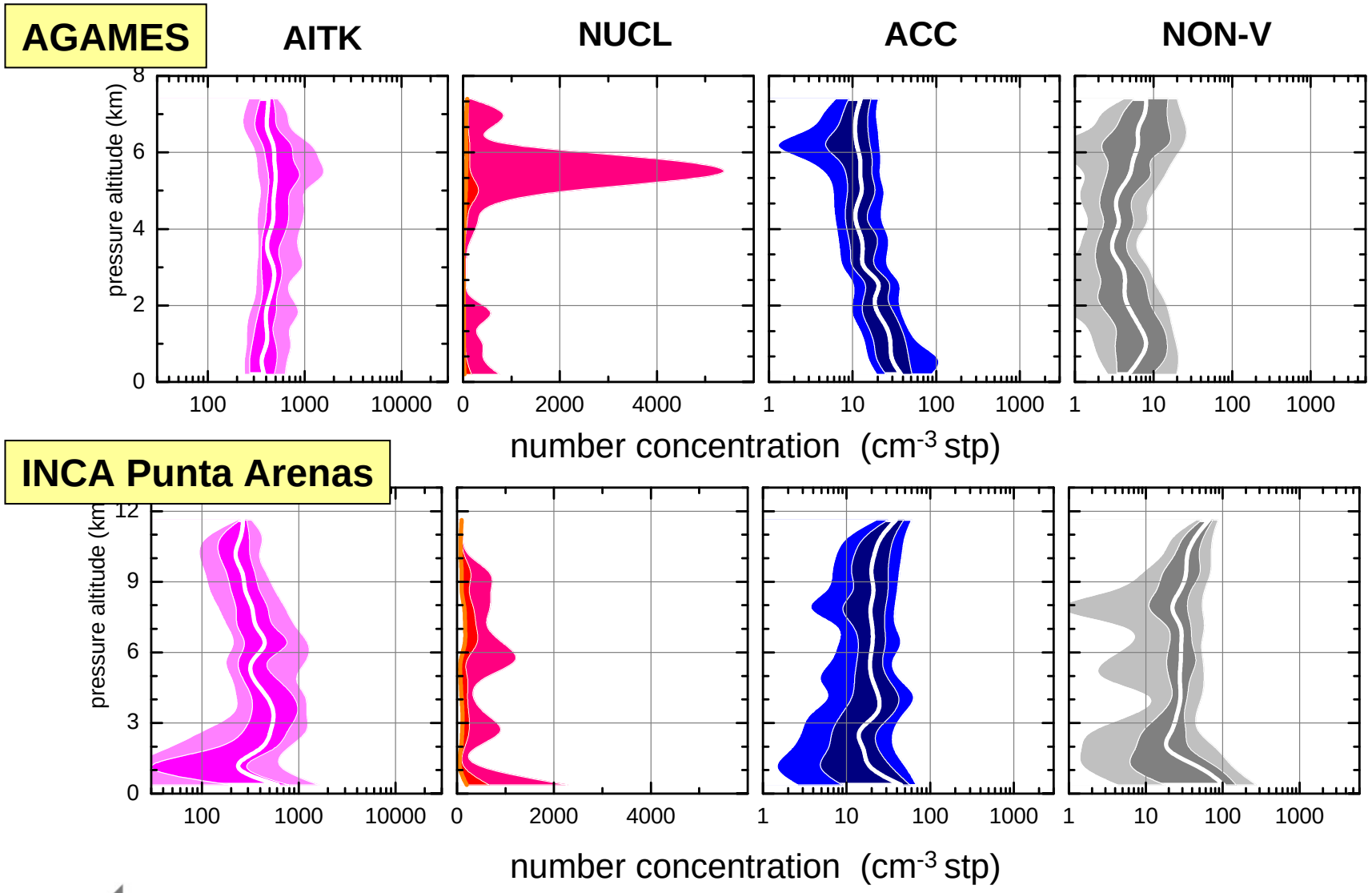


➔ sulfuric acid aerosol is likely dominating the aerosol number particularly above 3 km

Comparison of aerosol profiles

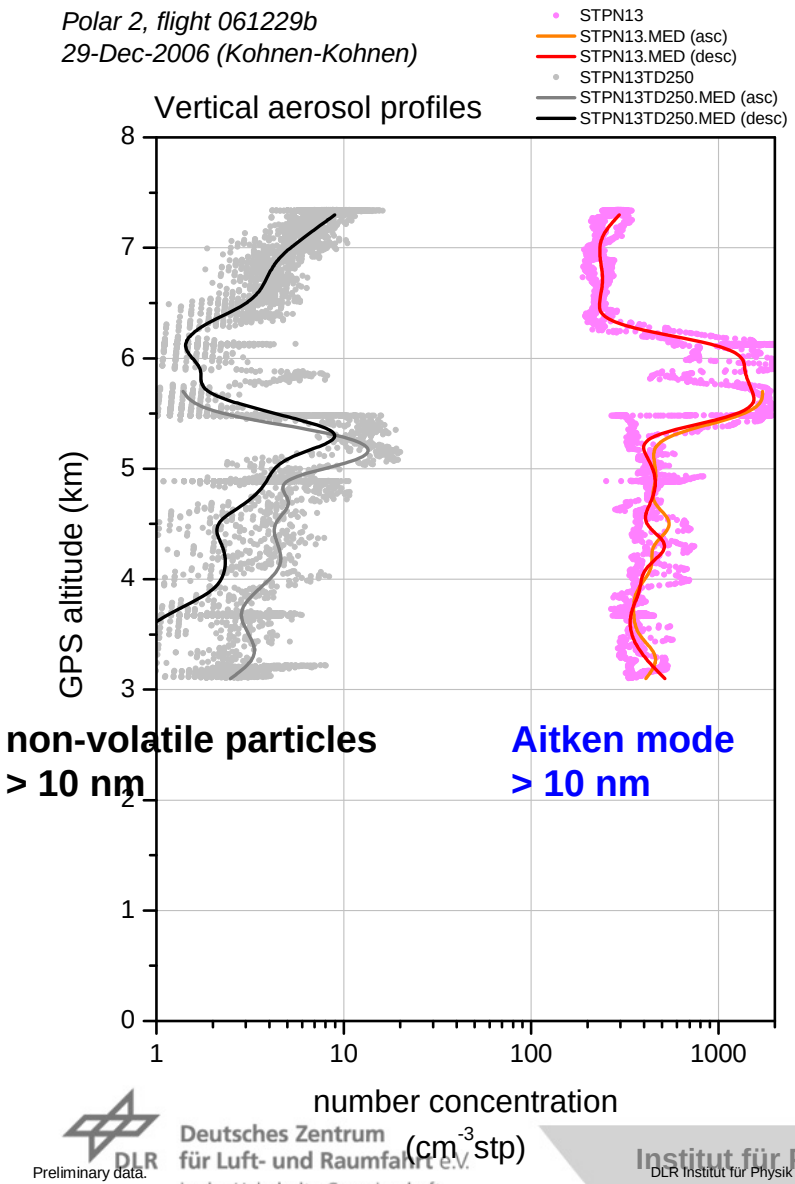


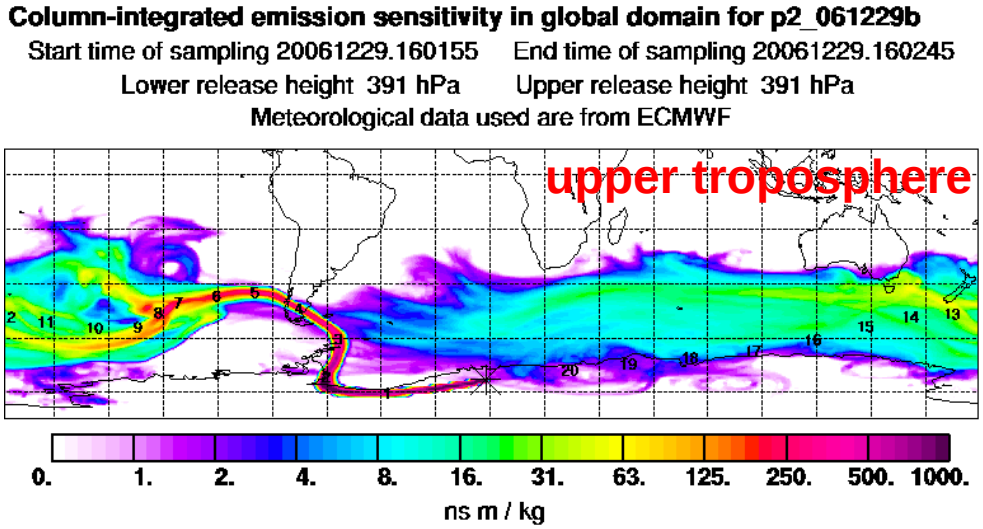
Comparison of aerosol profiles

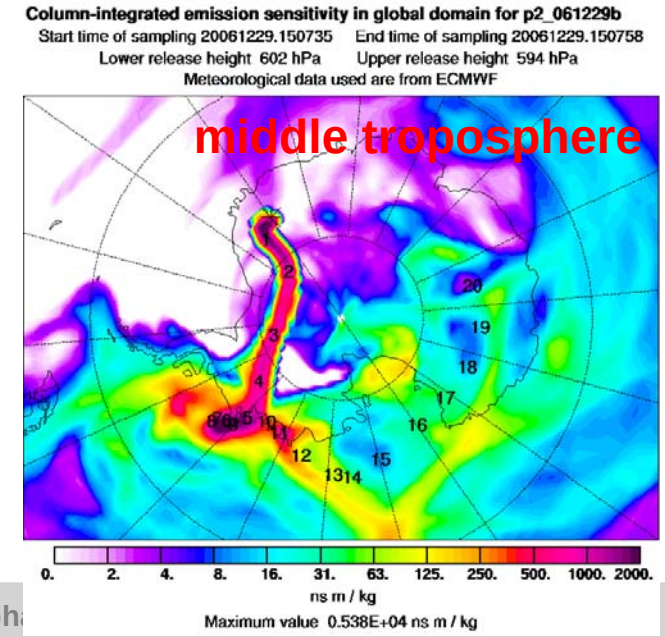


Layering in upper troposphere during flight from Kohnen

ANTSYO II / AGAMES
Polar 2, flight 061229b
29-Dec-2006 (Kohnen-Kohnen)

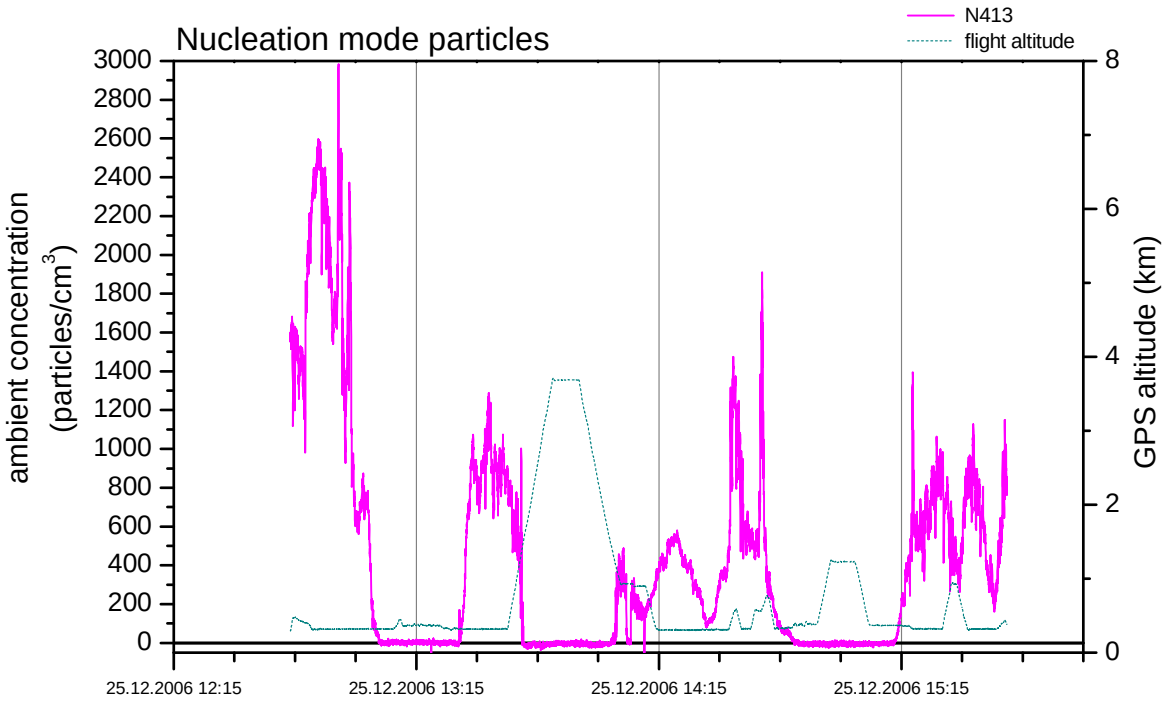


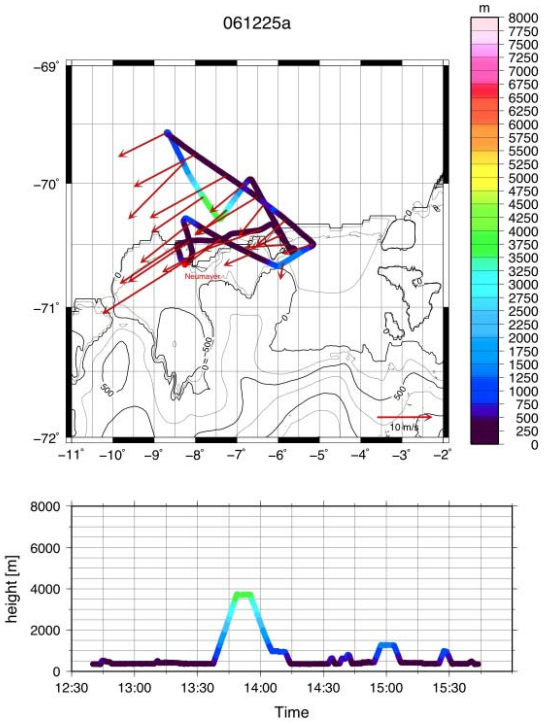




25-Dec-2006 case: particle nucleation at low level

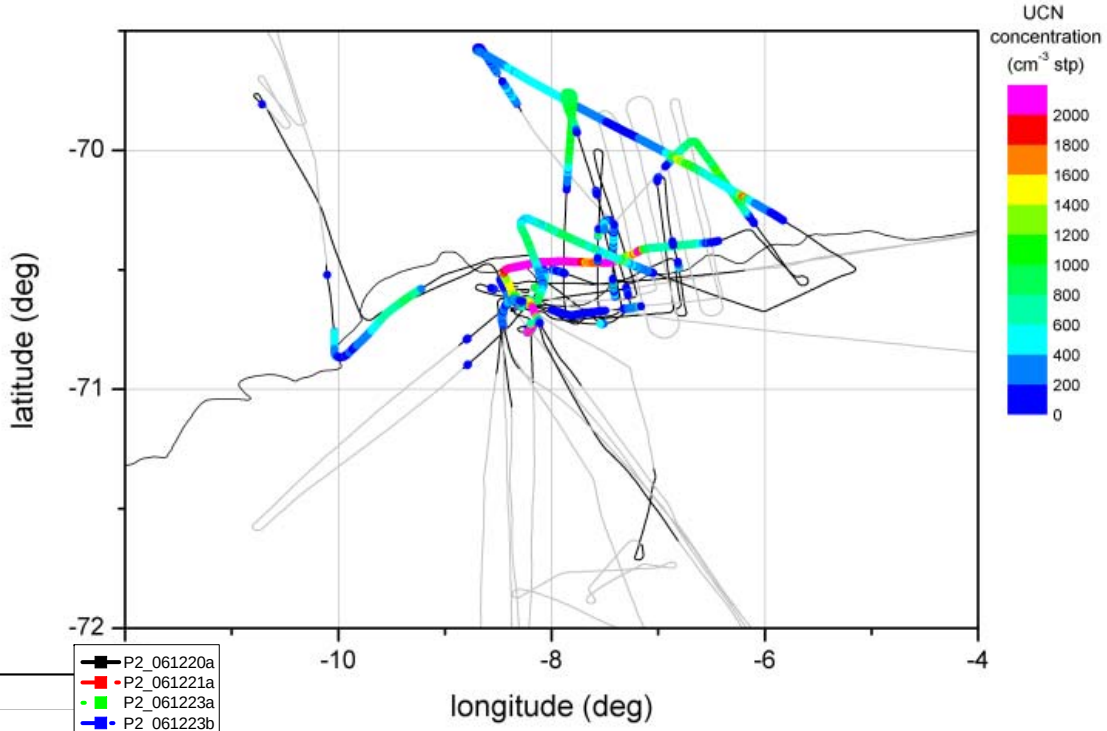
ANTSYO II / AGAMES
Polar 2, flight 061225a
25-Dec-2006

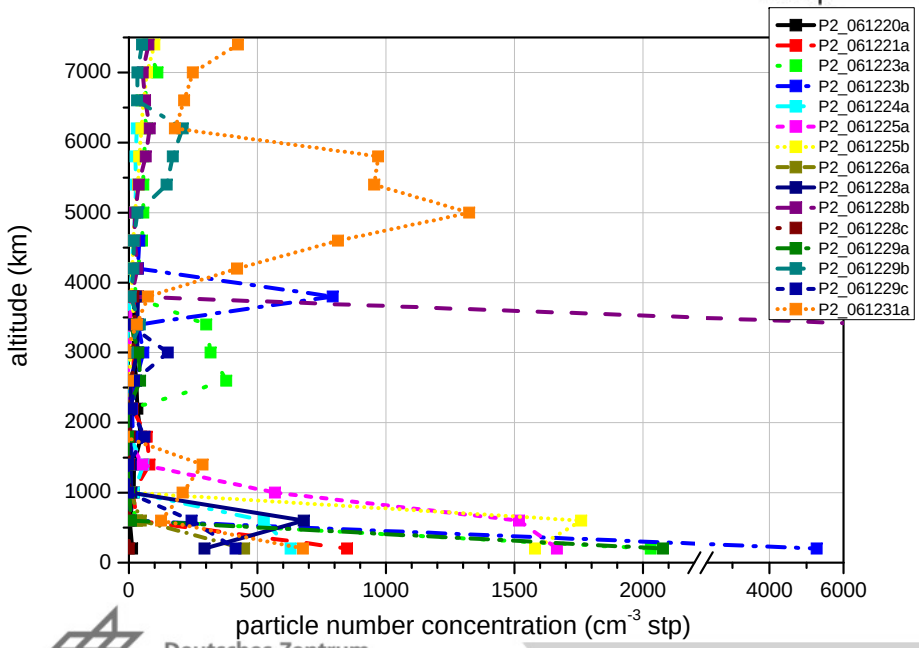




Particle nucleation at Neumayer

... was observed at low level predominantly over water

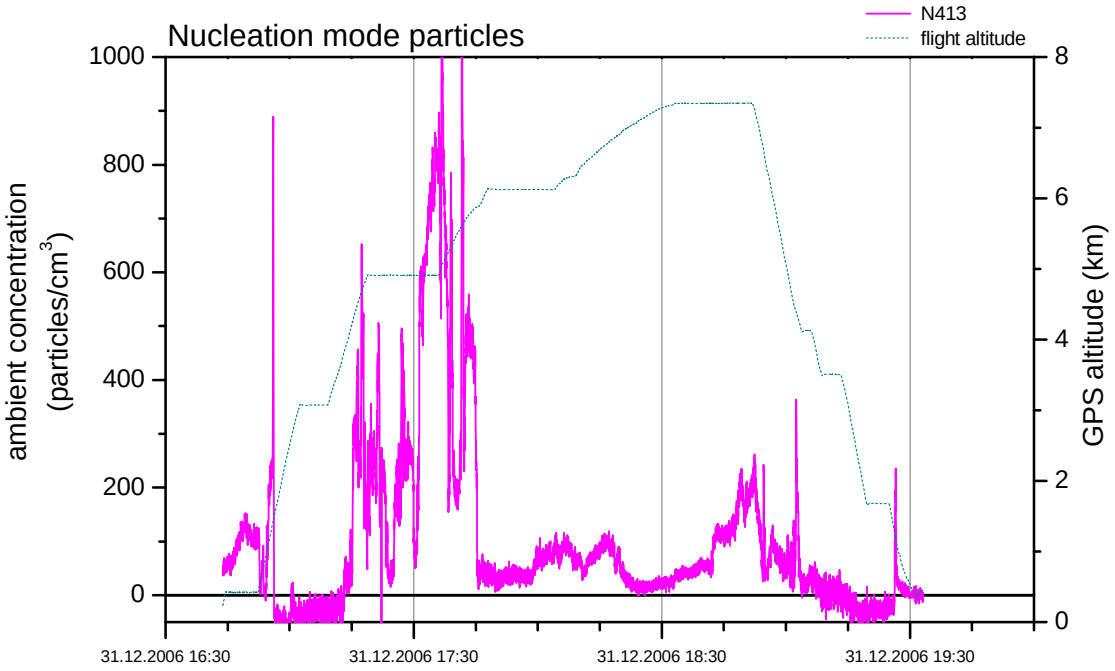


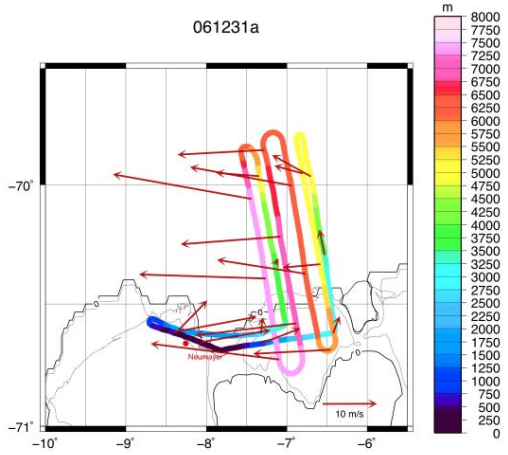


... was observed mostly at low level (below 1.5 km) with only few, but notable, cases of layers in the free troposphere

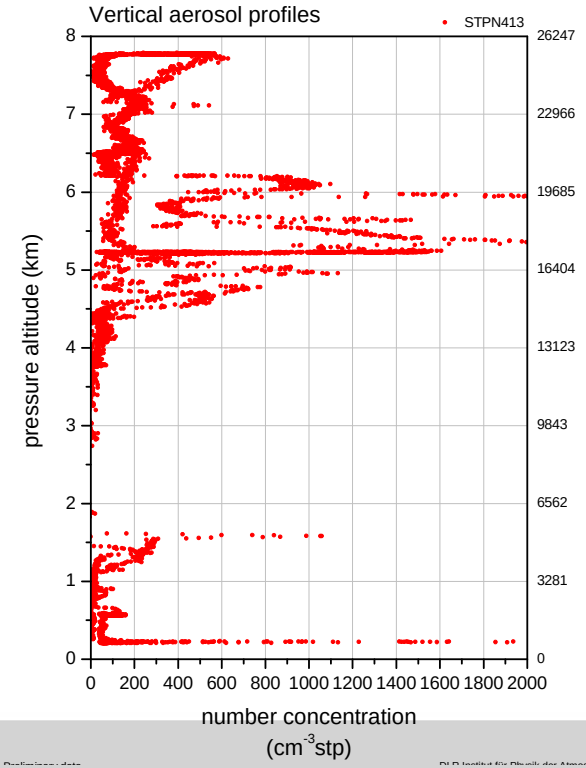
31-Dec case: high altitude particle nucleation

ANTSYO II / AGAMES
Polar 2, flight 061231a
31-Dec-2006





ANTSYO II / AGAMES
Polar 2, flight 061231a
31-Dec-2006



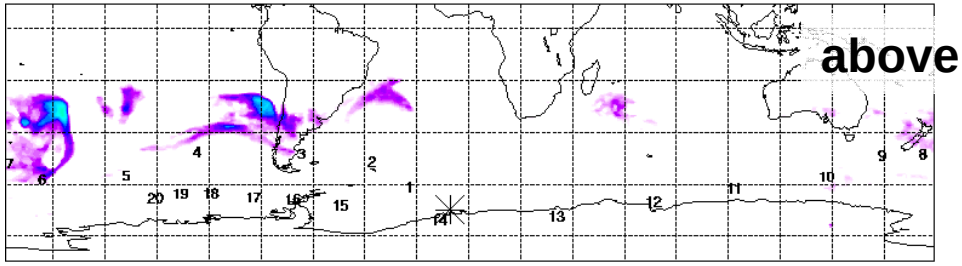
31-Dec case: high altitude particle nucleation, air mass origin

Footprint emission sensitivity in global domain for p2_061231a

Start time of sampling 20061231.180311 End time of sampling 20061231.180535

Lower release height 457 hPa Upper release height 449 hPa

Meteorological data used are from ECMWF

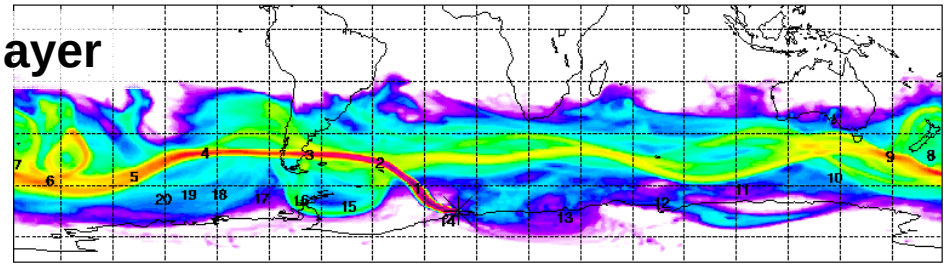


Column-integrated emission sensitivity in global domain for p2_061231a

Start time of sampling 20061231.180311 End time of sampling 20061231.180535

Lower release height 457 hPa Upper release height 449 hPa

Meteorological data used are from ECMWF



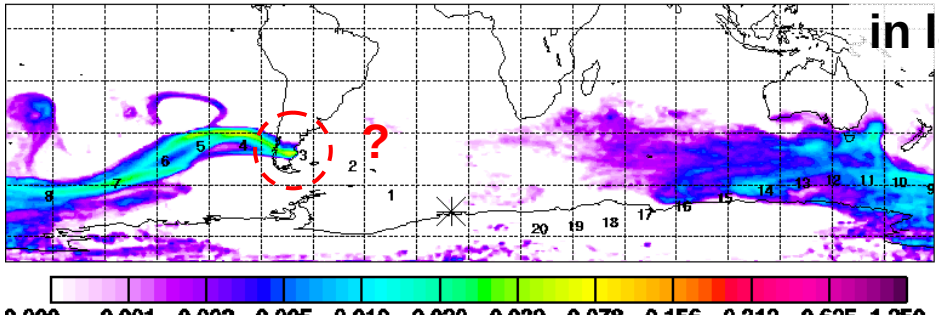
above layer

Footprint emission sensitivity in global domain for p2_061231a

Start time of sampling 20061231.173519 End time of sampling 20061231.173642

Lower release height 547 hPa Upper release height 539 hPa

Meteorological data used are from ECMWF

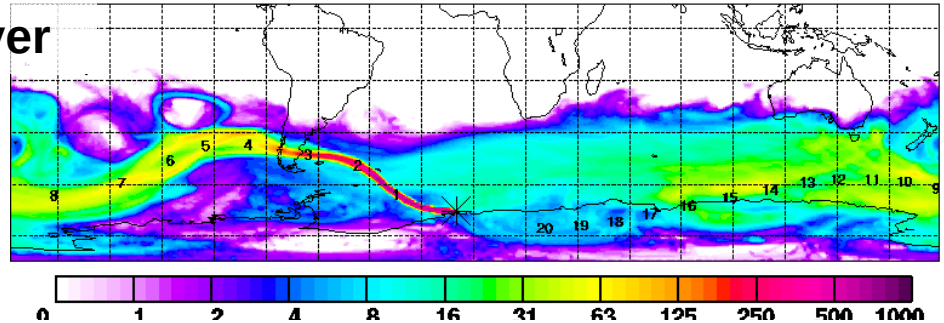


Column-integrated emission sensitivity in global domain for p2_061231a

Start time of sampling 20061231.173519 End time of sampling 20061231.173642

Lower release height 547 hPa Upper release height 539 hPa

Meteorological data used are from ECMWF



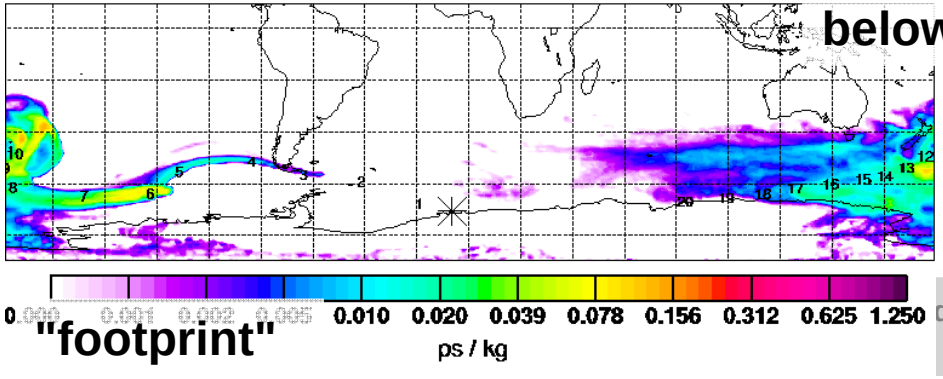
in layer

Footprint emission sensitivity in global domain for p2_061231a

Start time of sampling 20061231.170139 End time of sampling 20061231.170208

Lower release height 708 hPa Upper release height 700 hPa

Meteorological data used are from ECMWF

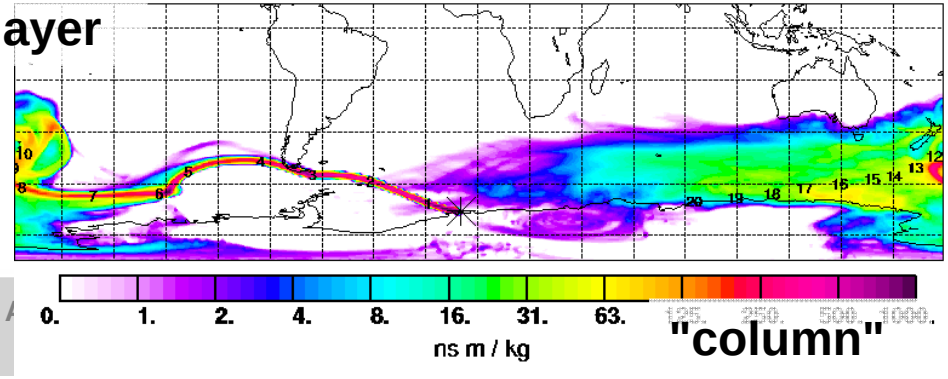


Column-integrated emission sensitivity in global domain for p2_061231a

Start time of sampling 20061231.170139 End time of sampling 20061231.170208

Lower release height 708 hPa Upper release height 700 hPa

Meteorological data used are from ECMWF



below layer

"footprint"

"column"

Conclusions

- first aircraft measurement campaign in Antarctic dedicated to the study of tropospheric aerosol properties in Dec/Jan 2006/7 (yes, that was before IPY)
- the vertical distribution of aerosol properties reflects in many ways the large distance to aerosol sources:

  - overall low particle number concentrations, in particular of non-volatile particles
  - weak vertical gradients in the free troposphere
  - relatively low variability (day-to-day, flight-to-flight)
  - prominent layers were rarely observed (and if, is South America the origin?)

- new particle formation (following probably DMS oxidation) did occur on local scale close to open water, but extending up to ~1.5 km altitude,

  but was also observed a few times in the upper troposphere (origin?)

- no significant aerosol gradients observed going from the coast to the continental and elevated sites on the Antarctic plateau
- particles of stratospheric origin mixed down to ~5 km altitude?

Acknowledgements

The AGAMES experiment was funded jointly by

- the Alfred Wegener Institute (AWI), Germany, and
- the National Institute for Polar Research (NIPR), Japan.

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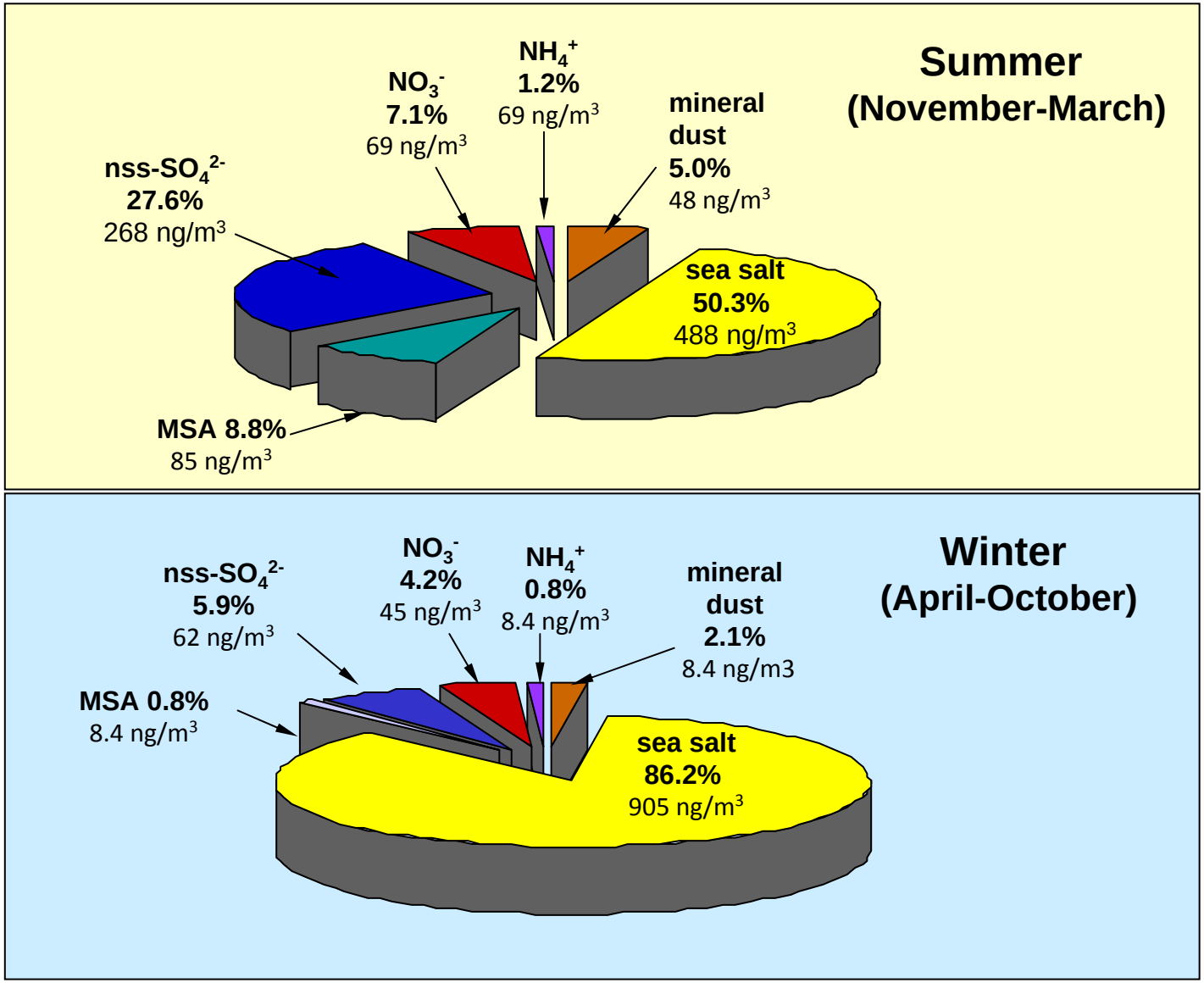
DLR was supported also by the Deutsche Forschungsgemeinschaft.

Many thanks for support of operations in Antarctica go to:

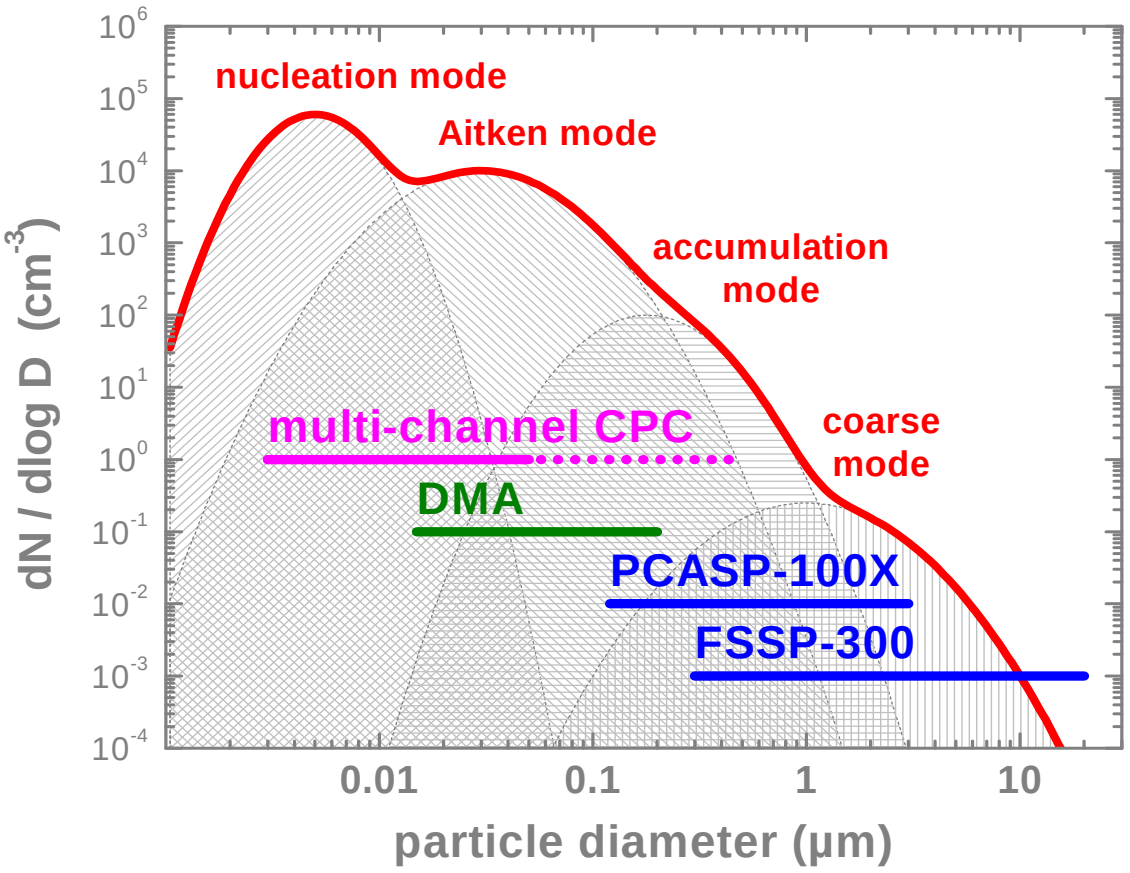
- The aircraft crew of DLR Braunschweig & Oberpfaffenhofen
- Optimare (Thomas & Jürgen)
- The staff at Neumayer
- The staff at Syowa

Spot the difference!


POLAR 2
D-CAWI


Summer
(November-March)
NH_4^+
1.2%
69 ng/m³
NO_3^-
7.1%
69 ng/m³
mineral
dust
5.0%
48 ng/m³
nss-SO_4^{2-}
27.6%
268 ng/m³
sea salt
50.3%
488 ng/m³
MSA 8.8%
85 ng/m³
Winter
(April-October)
NO_3^-
4.2%
45 ng/m³
NH_4^+
0.8%
8.4 ng/m³
nss-SO_4^{2-}
5.9%
62 ng/m³
mineral
dust
2.1%
8.4 ng/m3
MSA 0.8%
8.4 ng/m³
sea salt
86.2%
905 ng/m³

Particle size ranges covered by aerosol instruments onboard the Polar 2 aircraft



Polar 2 aerosol payload (microphysics)

MEASUREMENT	INSTRUMENT	AEROSOL CATEGORY	SIZE RANGE	OPERATED BY
CONDENSATION PARTICLE CONCENTRATION	**CPSA** condensation particle size analyser (4 channels) Heated inlet (125 °C, 250 °C)	**ultrafine (nucleation mode) & Aitken particles**	**> 4 nm > 9 nm > 13 nm**	DLR-IPA
		non-volatile, semi-volatile particles	**> 13 nm**	
AEROSOL SIZE DISTRIBUTION	**DMA ***	**Aitken mode aerosol**	**15–200 nm**	U-Stockholm, DLR-IPA
	PCASP-100X (& OPC)	**accumulation mode aerosol**	**0.12–3.5 µm** (dry)	
	FSSP-300	**coarse aerosol & cloud elements**	**0.3–20 µm**	
AEROSOL MIXING STATE	**Tandem-Volatility-DMA ***	**Aitken & accumulation mode aerosol**		U-Stockholm

Polar 2 aerosol payload (optical properties and chemistry)

MEASUREMENT	INSTRUMENT	AEROSOL CATEGORY	WAVE-LENGTH	OPERATED BY
AEROSOL OPTICAL PROPERTIES	Sun photometer	Spectral extinction coefficient	350-1050 nm	AWI
	Integrating nephelometer	Scattering coefficient	550 nm	NIPR Tokyo
	Particle Absorption photometer	Absorption coefficient	560 nm	U-Stockholm NIPR Tokyo
AEROSOL CHEMICAL COMPOSITION	Impactor sampling	Single particle analysis		NIPR Tokyo
	Filter sampling	Bulk chemical analysis		

Additional measurements:

- Position and wind data (Optimare, AWI)
- Humidity with CR-2 frost point hygrometer (AWI)
- Pyranometers & Pyrgeometer (Optimare, AWI)
- Flask sampling for greenhouse gases (NIPR)
- Aerosol with two OPCs (NIPR)

Vertical distribution of aerosol from Neumayer flights